EVALUATION OF A HIGH GRADE CONTINUOUS CENTRIFUGAL

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Abstract

A high grade continuous centrifugal was commissioned at Deep River Beau Champ sugar factory near the end of the 1995 crushing season. When operated in parallel with a batch machine, it was observed that the continuous centrifugal produced a higher purity rise in the A-runnings by 0,5 unit, a higher agglomeration of the sugar by 2,4% and a higher crystal breakage of 2,1%. The capacity of the A-centrifugal station increased two-fold, and the energy requirement per ton massecuite was reduced three-fold.

Keywords: Continuous centrifugal, crystal breakage, agglomerate.

Introduction

Sugar technologists throughout the world have tried for decades, with little success, to operate or modify low grade continuous centrifugals for curing high grade massecuites (Credoz *et al.*, 1977; de Robillard and Journet, 1980; Swindells and Kirby, 1981). The objectives were (1) to increase the massecuite throughput and thus reduce the power consumption, and (2) to provide the possibility of processing not only viscous massecuites but also poor strikes with irregular crystals or fine grains so as to improve molasses exhaustion and boiling house recovery. The failure is attributed mainly to the poor quality of the sugar crystals obtained; high % lumps and high crystal breakage evidenced by the high % fines, which are not acceptable in commercial sugar. Centrifuging of A-massecuite has therefore remained a batch process.

Historical

Goodacre *et al.* (1984) indicated possible design modifications to overcome the difficulties mentioned above and, in 1993, the breakthrough came when research in Australia (Kirby *et al.*, 1990; Greig *et al.*, 1992) culminated in the development of a prototype centrifugal for high grade massecuites called STG (Schultz, Tait and Greig). Design efforts (Greig and Belotti, 1995) were concentrated on controlling the trajectory of crystals after leaving the basket rim so as to decelerate and deliver them to the sugar chamber without breakage, and on creating a self-cleaning impact surface to prevent build-up of lumps. Compared with low grade continuous centrifugals, the high grade has a lower speed (800 compared with 1 500 rpm) and higher washing rate with finer jets.

The advent of the first high grade continuous centrifugal revolutionised the sugar scene and, by 1995, its commercialisation led to its adoption by the Australian sugar industry for high grade massecuites in the raw house as well as for strikes in the refinery. Deep River Beau Champ (DRBC) sugar factory, with a crushing capacity of 180 tons cane per hour, had to refurbish their high grade centrifugal station for the 1995 crop, to replace the two old batch BMA Variants bought in 1974. (A third one was bought in 1983.) It was decided to order an STG 110 HR which was supplied by Fives-Cail Babcock (FCB) and commissioned near the end of the 1995 crushing season.

Design characteristics

The continuous centrifugal is made entirely of stainless steel, and is driven by an electric motor. It has a vertical shaft and a side feeding arrangement. The massecuite feed must be at 55°C minimum, re-heated by low pressure steam and assisted by water addition. The vertically mounted conical basket with an angle of 25° and long screen length results in a high G factor to achieve good separation efficiency. The screen used is chromium plated nickel with 0,15 mm opening and 1,5 m^2 centrifuging surface. A drawing of the continuous centrifugal is shown in Figure 1.

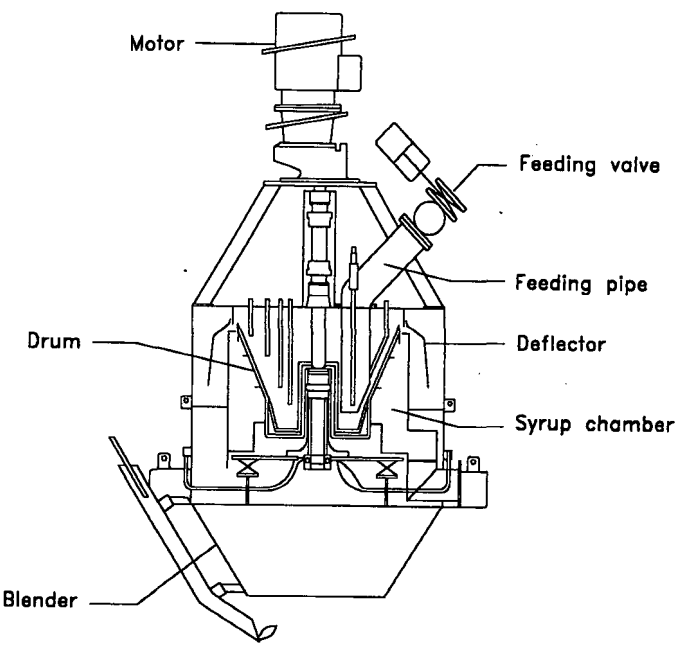

FIGURE 1: Schematic drawing of STG 110 HR continuous centrifugal

The rate of washing and steaming in the continuous centrifugal is higer than in a batch machine, and contributes to better separation efficiency. A static deflector provides a controlled trajectory through the special basket geometry and low angles of impact for the crystals leaving the basket rim. Thus the crystal velocity is lower than the critical speed of 48 m/s, below which the product sugar is free of broken crystals (Swindells and White, 1980). This arrangement, together with the low speed of the continuous centrifugal, reduces the incidence of crystal fracture.

A self-cleaning blender massages/blends the crystals before they leave the monitor casing to avoid agglomerate for-

mation. Compared with sugar cured by a batch machine, continously cured sugar is hotter (65°C) and wetter (1,0-1,4% moisture).

The nominal power of the centrifugal installed is 45 kW. At a massecuite throughput of 50 t/h, and at 850 rpm, the power consumed is about 35 kW. The machine is fully Programmable Logic Control (PLC) automated with remote sequenced start/stop, automatic control of the feed valve to provide a steady load, and automatic control of wash water flow as a function of massecuite feed rate (Greig and Belotti, 1995).

The dryer used was an existing rotary dryer, with diameter and length of 2 690 mm and 7 620 mm respectively, a nominal power rating of 89 kW and a capacity of 25 t/h. The temperature of the vapour used was 80°C and the air/sugar ratio was 0,7 by weight (Schinkel and Tait, 1994).

Experimental

The STG 110 HR continuous centrifugal was installed in early November 1995, with three crushing weeks remaining after commissioning was completed. Because of the teething problems encountered during the installation, the factory could not handle the additional volume of A-runnings resulting from the higher rate of washing in the continuous machine, following the adoption of the recommended 6,5% of wash water to massecuite feed. An acceptable compromise was reached with 4% wash water. All experiments were carried out at this washing rate except where indicated.

Comparison of continuous and batch machines

Experiments were designed to compare, at various massecuite feed rates, the performance of the continuous centrifugal with the batch (1973) BMA Variant of 1 250 mm diameter and 1 000 mm depth, with screen size of 0,40 mm working at 1 500 rpm.

The two centrifugals were operated in parallel with the same massecuite feed. Sampling facilities were installed so that A-runnings and sugars issuing from the two machines could be sampled independently. Sampling was carried out every ten minutes over a period of one hour.

Parameters studied were massecuite feed rate and purity, and purity rise across the centrifugal using Nutsch purity. Sugar quality was also assessed in terms of moisture, pol, purity, ICUMSA colour, % lumps, grain size (mean aperture MA, coefficient of variation CV) and % fines (<600 microns). Crystal breakage is defined as the difference in fines (<600 microns) produced in continuous with respect to the batch centrifugal as adopted by Griffin and Borchardt (1990) (other workers have used a sieve size of 300 microns), as much of the fines did not pass through the 300 micron sieve.

All analyses were carried out in accordance with the Mauritian Official Methods (STASM, 1991) except for the determination of lumps. This was evaluated as a percentage by weight of all the dark agglomerates in a sample of known mass.

As the raw sugar leaving the continuous centrifuge was very wet, grain size could not be determined on an oven-dried sample due to caking. This difficulty was overcome by adopting the method of Vignes (1977), which involves adding sugar-saturated methanol immediately to the sampled sugar, rinsing successively with sugar-saturated isopropanol, before drying in a rotary film evaporator and subsequently sieving. Sugars cured by both continuous and batch centrifugals were treated in the same manner. However, drying using a rotary film evaporator was not employed as the procedure was time-consuming, and a hand dryer was used instead. Greig *et al.* (1995) used oven drying after alcohol washings and experienced sugar agglomeration.

Wash water to massecuite feed rate and drying operation

For massecuite feed rates of 30, 40 and 50 t/h, the wash water flow was varied manually so that water to massecuite ratios were 6,5, 4,0 and 3,0%, and the effect on the sugar quality was noted. Each experiment lasted for 30 minutes.

In order to assess the performance of the dryer, the lag time of the sugar from the centrifugal to the dryer exit was determined by stopping the centrifugal and noting the time taken for the sugar to travel from the centrifugal discharge to the dryer exit. Sugar before and after the dryer was sampled for one hour (every 10 minutes) with a lag time of 20 minutes. Grain size and % fines were determined as described above.

Results and discussion

Batch versus continuous centrifugals

Averages of duplicate results on sugar cured by batch and continuous machines at various massecuite feed rates are presented in Table 1.

The mean A-runnings purity is 0,5 unit higher at the continuous than at the batch centrifugal. This is contrary to the findings of Greig and Belotti (1995), who reported that molasses purity from the continuous machine is 0,5-2,0 units lower than that from a batch machine. The mean purity rise in the continuous centrifugal is from the Nutsch purity of 65,5 to the A-runnings purity of 69,1, ie 3,6, compared with from 65,5 to 68,6, ie 3,1 in the batch machine. The difference in purity rise is significant (P=0,1).

Table 1

Comparison of sugar quality cured by batch and continuous centrifugals

Mcte t/h	Water L/min	Mcte purity	Nutsch purity	Batch								Continuous							
				A-molasses purity	Moisture %	Pol	ICUMSA colour	Lumps %	Fines % <600 µ	MA µ	CV %	A-molasses purity	Moisture %	Pol	ICUMSA colour	Lumps %	Fines % <600 µ	MA µ	CV %
45	22,0	84,8	65,5	68,7	0,82	98,76	1 077	-	17,89	820	29,9	69,6	1,16	98,09	1 483	-	20,45	790	29,7
40	17,1	86,8	65,6	68,6	0,85	98,26	1 090	-	13,73	860	28,4	69,3	1,57	98,29	2 369	-	17,31	810	28,3
35	13,2	85,1	66,7	69,9	0,75	98,79	1 022	0,15	0,70	1 100	21,9	69,8	1,86	97,17	1 555	4,15	1,20	1 190	23,7
35	16,7	86,6	64,3	67,9	0,92	97,92	1 835	0,13	0,95	980	22,3	68,4	1,42	97,58	1 493	1,55	1,87	990	24,7
30	14,0	86,4	65,6	68,3	0,72	98,43	1 612	0	0,55	970	23,5	68,3	1,36	97,68	1 345	1,93	4,98	920	25,4
25	10,8	86,6	65,0	68,2	1,20	97,38	2 028	0	0,65	1 260	20,1	69,4	2,13	96,37	1 952	2,40	1,40	1 270	21,7
Mean		86,1	65,5	68,6	0,88	98,26	1 444	0,07	5,75	1 000	24,4	69,1	1,58	97,53	1 700	2,50	7,87	1 000	25,6

Table 2

Typical sugar quality cured by STG continuous centrifugal

Massecuite (t/h)	Water L/min	Massecuite purity	Nutsch purity	A-molasses purity	Moisture %	Pol	ICUMSA colour	Lumps %	Fines % <600 µ	MA µ	CV %
50	21	87,4	67,4	71,5	2,31	96,38	1 936	-	1,40	1 070	27,8
45	22,0	87,4	66,5	69,1	2,14	96,53	2 080	2,58	1,75	1 070	27,4
45	23,4	86,5	66,4	68,5	2,01	97,05	2 014	-	6,89	820	21,8
40	16,8	86,0	64,9	68,5	1,80	97,62	1 622	-	14,57	760	21,3
40	17,1	86,7	66,6	69,6	1,60	97,69	1 714	-	7,31	940	22,9
40	17,1	86,8	65,6	69,3	1,57	97,39	2 369	-	17,31	810	28,3
35	16,7	86,6	64,3	68,4	1,40	97,75	1 647	1,55	1,68	970	24,5
35	13,2	85,9	66,8	70,4	1,98	96,92	1 740	1,82	0,67	1 220	20,9
30	14,4	86,5	65,9	68,7	1,37	97,68	1 330	1,58	4,98	990	23,2
25	10,8	87,6	64,9	69,3	2,09	96,50	1 942	2,70	3,50	920	26,4
25	11,5	86,9	65,0	69,0	1,73	98,25	1 562	-	-	-	-
Mean		86,8	65,8	69,3	1,82	97,24	1 814	2,05	6,01	960	24,5

As expected, average sugar moisture is higher (P=0,01) at 1,58% compared with 0,88% from the batch machine. Pol of the continuously cured sugar is lower (P=0,05) at 97,53 compared with 98,26.

Average ICUMSA colour of the product sugar from the continuous centrifugal was higher at 1 700 compared with 1 444 from the batch process. There are definitely more agglomerates from the continuous centrifugal at 2,50% compared with 0,07% from the batch centrifugal (P=0,05), although the actual level of 2,50% lumps is not high. As for fines, it is noted that at the massecuite feed rates of 45 and 40 t/h, % fines in sugars cured by both continuous and batch centrifugals are high at 13-20%, this being due to the high proportion of fine grain in the massecuite during that particular trial period. The difference in the % fines for the continuous (7,87%) and batch (5,75%) centrifugals is significant (P=0,05), and the % crystal breakage due to the continuous centrifugal can be quantified as 2,1%, which is quite insignificant. There is no significant difference in crystal size distribution in sugars leaving the continuous and batch centrigugals, as evidenced by the values of mean apertures and coefficients of variation.

If the recommended higher wash water to massecuite feed rate had been applied, the pol of the sugar would have been higher with a lower sugar colour and higher purity rise in the continuous centrifugal.

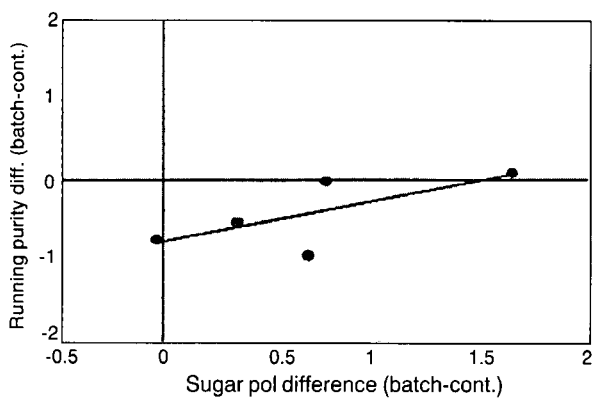

FIGURE 2: Relative sugar pol between batch and continuous centrifugals versus the corresponding differential in sugar polarisation

Figure 2 shows a plot of the pol difference between sugars leaving the batch and continuous machines versus the purity difference in runnings for the same massecuite. The trend indicates that a batch machine producing the same sugar pol as a continuous machine will also produce the same or similar purity of the runnings. (It is noted that the sugar pol at 25 t/h massecuite is lower than expected; the related data in Table 1 have not been taken into consideration in plotting Figure 2.)

During the trial period, the blender was not functioning for several days due to a bearing failure. The sugar cured was full of dark agglomerates, and was obviously of unacceptable quality. Analytical results of these samples were not taken into consideration.

The capacity of the centrifugal station increased from about 24 to 40 t/h with the continuous machine. The installed power was 100 kW for the batch machine compared to 45 kW for the continuous centrifugal, if the two machines were assumed to be working at their maximum installed power, because of the energy recuperated at making of the batch centrifugal, calculated to be 23 %, the energy consumed by it would be 77 kW per hour compatred to 45 kW per four for continuous machine. For each ton of massecuite processed, the energy consumed would be respectively 3,2 and 1,1 kW/h.

Typical sugar quality cured by STG continuous centrifugal operating at various massecuite feed rates is shown in Table 2. The massecuite purities were all within the specification of 85-88. Purity rise in the centrifugal was 3,5 units, average sugar moisture was high at 1,82% and average sugar pol was slightly low at 97,24 for a target sugar pol of 98,7.

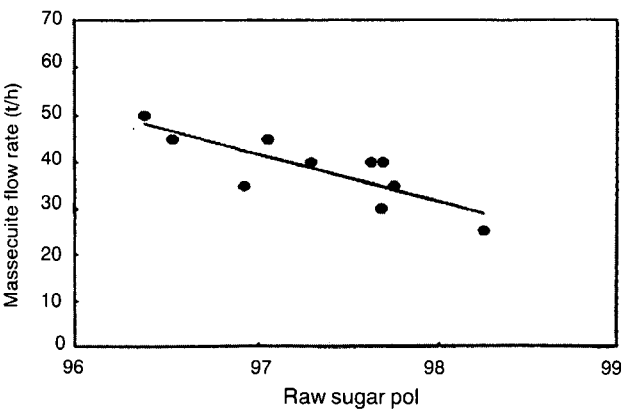

FIGURE 3: Massecuite processing capacity as a function of raw sugar polarisation

Table 3

Effect of water wash rate on sugar quality cured by continuous centrifugal

Water wash rate (%)	Massecuite t/h	Massecuite purity	Nutsch purity	A-molasses purity	Moisture %	Pol	ICUMSA colour	Lumps %	Fines % <600 μ	Fines % <355 μ	MA μ	CV %
6,5	50	87,2	65,9	68,5	2,11	97,09	1 732	0,66	35,00	5,52	690	32,2
	40	86,6	66,4	70,2	2,42	95,13	1 705	0,30	26,86	0,32	760	30,4
	30	87,3	66,8	70,6	2,01	97,40	1 265	0,73	21,45	1,90	840	35,1
	Mean	87,0	66,4	69,8	2,18	96,54	1 567	0,56	27,77	2,58	763	32,6
4,0	50	87,1	65,4	68,2	2,39	96,36	2 225	1,12	23,81	2,84	760	30,9
	40	87,6	67,3	70,5	2,46	95,97	2 121	3,17	33,08	0,94	720	31,9
	30	87,2	66,2	69,6	2,15	96,69	1 713	1,52	33,26	3,94	690	30,4
	Mean	87,3	66,3	69,4	2,33	96,34	2 020	1,94	30,05	2,57	723	31,1
3,0	50	86,7	64,7	68,2	1,87	95,94	2 472	0,15	27,65	3,85	730	30,3
	40	87,0	67,1	70,2	2,36	95,95	2 287	3,06	11,88	0,55	890	30,4
	30	87,1	66,2	68,9	2,19	96,71	1 962	0,42	-	-	-	-
	Mean	86,9	66,0	69,1	2,14	96,20	2 240	1,21	19,77	2,20	810	30,4

The average % lumps amounted to 2,05%, which was not high. However, % fines were high at 6,01%, which was due to the factory producing fine grain as mentioned earlier, and it must be remembered that % fines have been defined as those particles passing through a 600 μ sieve. Sugar grain size distribution is indicated by the mean aperture of 960 μ and has a coefficient of variation of 24,5%. The massecuite processing capacity is plotted in Figure 3 as a function of raw sugar polarisation (again, the outlier in pol value at 25 t/h massecuite is not taken into consideration) and was found to be closely related.

Wash water/massecuite feed rate

The effect of wash water rate on sugar quality cured by the STG continuous centrifugal is shown in Table 3. It is observed that, at the various wash water rates of 6,5, 4,0 and 3,0% on massecuite feed rate, the sugar moisture and pol values are comparable. At the higher water rate of 6,5% the ICUMSA colour of the product sugar is lower and there is less agglomeration. The high % fines obtained through a 600 μ sieve were again due to a high proportion of fine grain during this trial period. However, when the sugar fractions of the same sample going through a 355 μ sieve were examined, % fines amounted to only about 2%.

Dryer operation

Analytical results on product sugar quality before and after drying are presented in Table 4. Owing to the short time available for the trial, only three pairs of comparison were possible for the crucial % fines data.

It can be observed that, after drying, the sugar moisture drops from 1,84 to 0,43%, which is still high. The dilution indicator of the raw sugar obtained at DRBC during the 1995 crop was in fact too high (target value 25-40) and steps have to be taken either to decrease the air/sugar ratio, or to decrease sugar feed moisture by increasing the water temperature in the continuous centrifugal to as high as possible, between 85-90°C.

The pol value increased from 97,35 to 98,70 while purity remained the same at 99,13. ICUMSA colour of the sugar did not change after drying, and was therefore not determined on dried sugar. For the three samples of sugar before and after drying, the mean % fines, mean aperture (MA) and coefficient of variation (CV) were respectively 3,4%, 1 041 μ and 24,5% before drying and 11,6%, 907 μ and 30,2% after drying. Hence, the % grain fracture occurring in the dryer can be calculated to be 8,2% for both batch and continuously dried sugar, however, because of the limited data, the dryer performance needs to be further studied.

Conclusions

It has been demonstrated that the continuous centrifugal can be used successfully for the curing of A-massecuites. The capacity of the A-centrifugal station increased from about 24 to 40 t/h while the power requirement decreased from 3,2 to 1,1 kW per ton massecuite processed. Although the product sugar moisture was higher, the dryer coped well. Agglomerates due to the continuous centrifugal increased to 2,4% while crystal fracture was estimated at 2,1%.

Table 4

Quality of product sugar before and after drying

Before drying							After drying					
Moisture %	Pol	Purity	ICUMSA colour	Fines % <600 μ	MA μ	CV %	Moisture %	Pol	Purity	Fines % <600 μ	MA μ	CV %
2,31	96,38	98,65	1 936	1,4	1070	27,8	0,58	98,22	98,79	-	-	-
2,01	97,05	99,04	2 014	-	-	-	0,38	98,57	98,94	6,89	820	21,8
1,80	97,62	99,41	1 622	-	-	-	0,21	98,92	99,13	14,57	760	21,3
1,49	97,87	99,35	1 505	1,14	1030	20,3	0,44	98,68	99,12	15,44	850	31,5
1,82	97,47	99,28	1 893	1,88	1030	22,6	0,32	98,95	99,26	0,68	920	28,2
1,48	97,72	99,18	1 744	18,92	760	25,8	0,34	98,97	99,30	-	-	-
1,96	97,32	99,27	1 866	7,20	1060	30,6	0,77	98,57	99,34	9,76	950	30,8
1,84	97,35	99,17	1 797	3,41*	1041*	24,5*	0,43	98,70	99,13	11,63*	907*	30,2*

* Mean of the three results where comparisons are possible.

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